Status of the MIPP Experiment

Jonathan M. Paley

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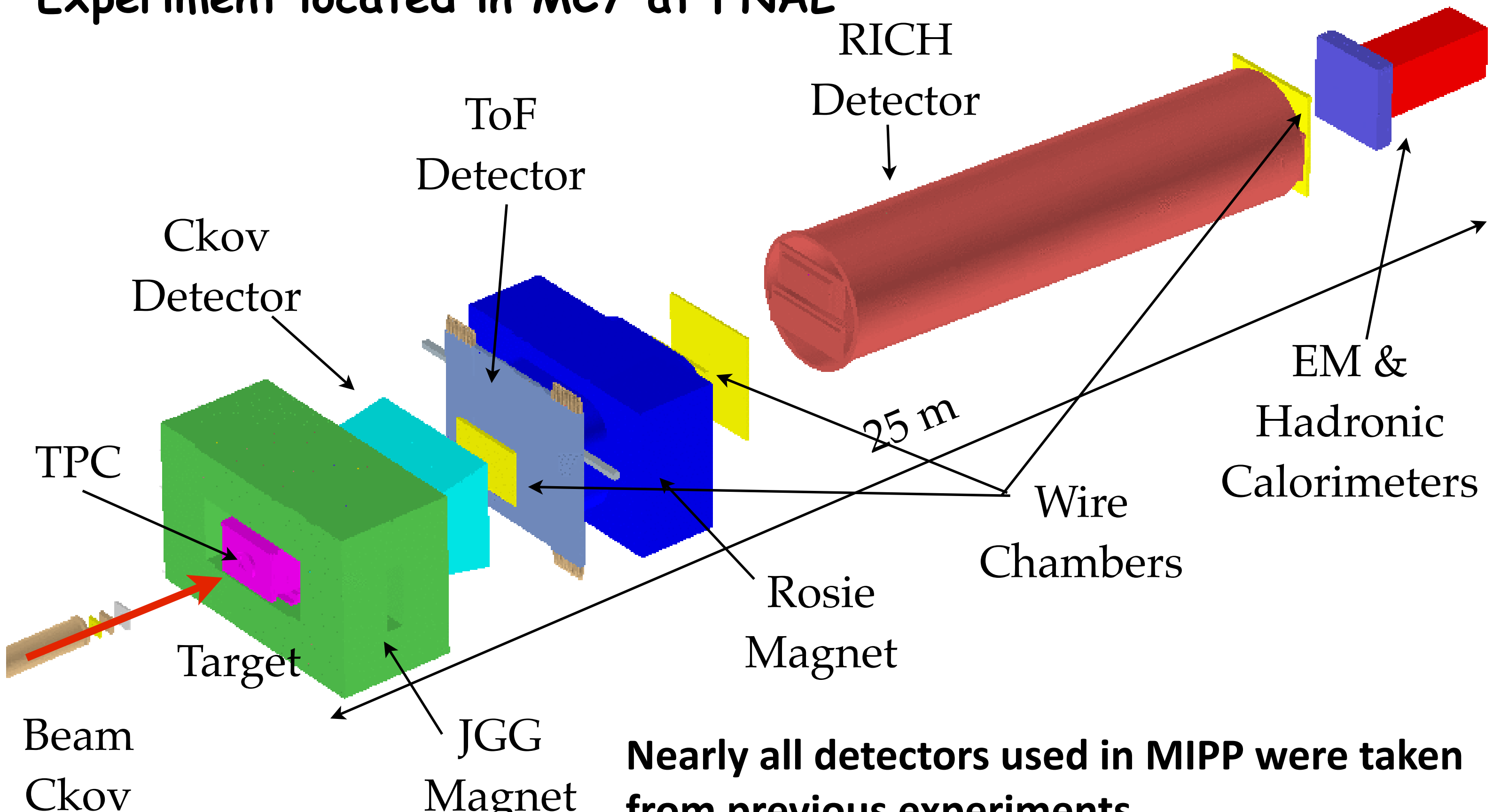
Main Injector Particle Production (MIPP) Experiment

Experiment located in MC7 at FNAL



Nearly all detectors used in MIPP were taken from previous experiments.

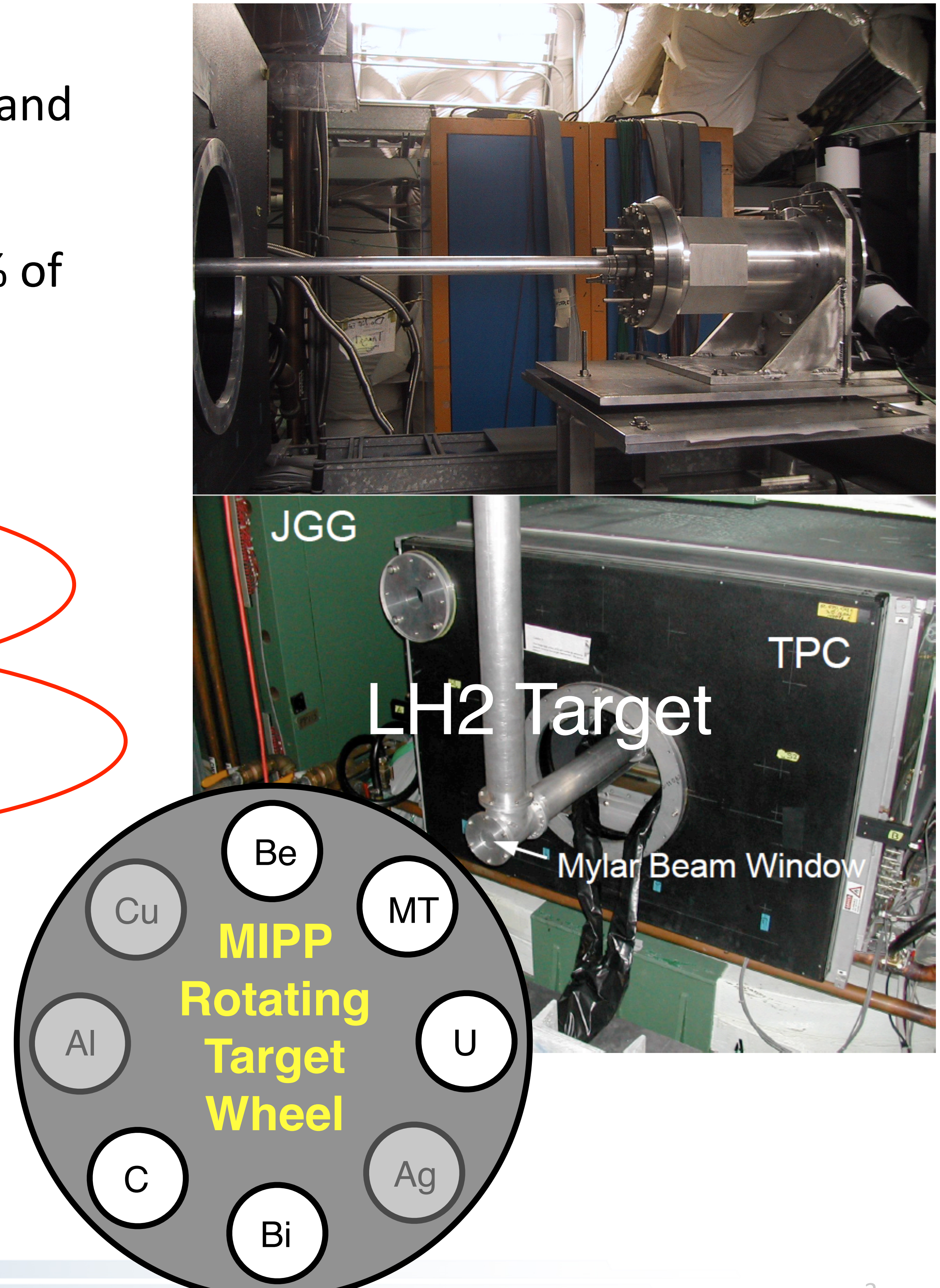
- Goal: collect comprehensive hadron production cross-section data set with particle id using various beams and targets (thick and thin).

- Full acceptance spectrometer
- Two analysis magnets deflect in opposite directions
- TPC + 4 Drift Chambers + 2 PWCs

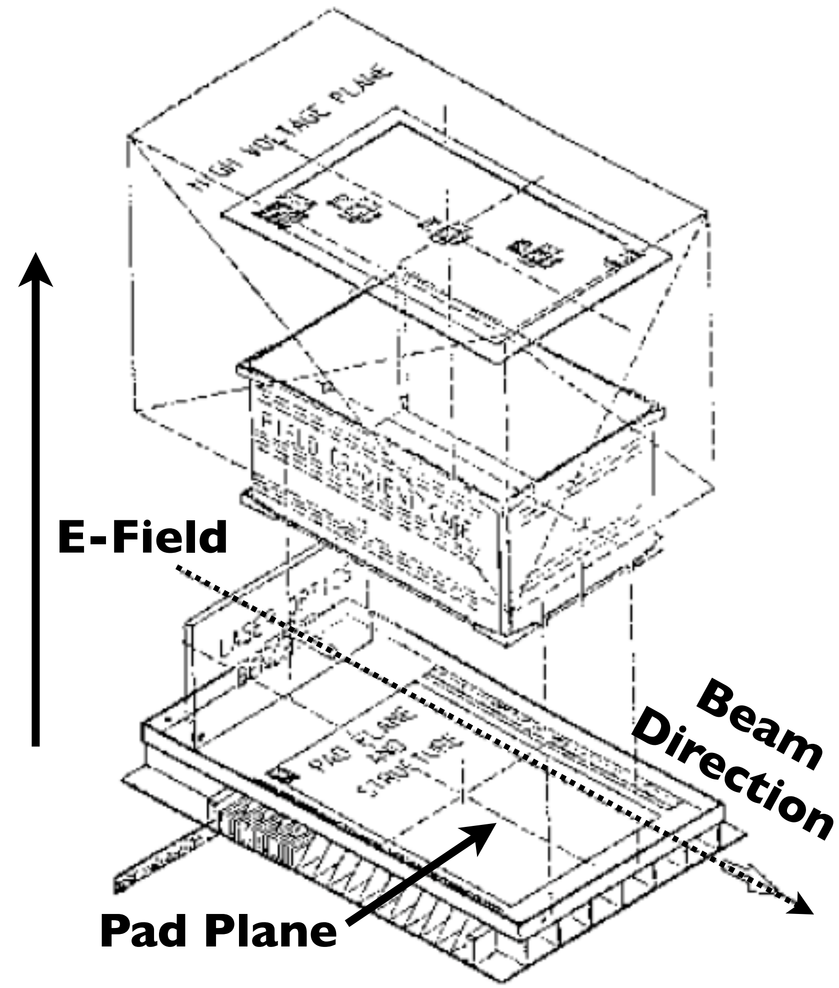
- Designed for excellent particle ID (PID) separation (2-3σ)

The 2005-06 Data Run

- MIPP began its physics run in December 2004 and ran until February 2006.
- DAQ rate was ~25 Hz, with MIPP receiving ~5% of MI beam.
- Data collected:
- ~1.6 x 10^6 events of Main Injector 120 GeV/c protons on a spare NuMI target.
- ~3.2 x 10^6 π's, K's and p's at 120, 60, 35 and 20 GeV/c on 1-2% λ_L C and Be targets.
    - ~7 x 10^6 π's, K's and p's at 85, 60, 20 and 5 GeV/c on 1% λ_L LH2 target.
    - ~4 x 10^6 π's, K's and p's at 35, 60 and 120 GeV/c on Bi and U targets.

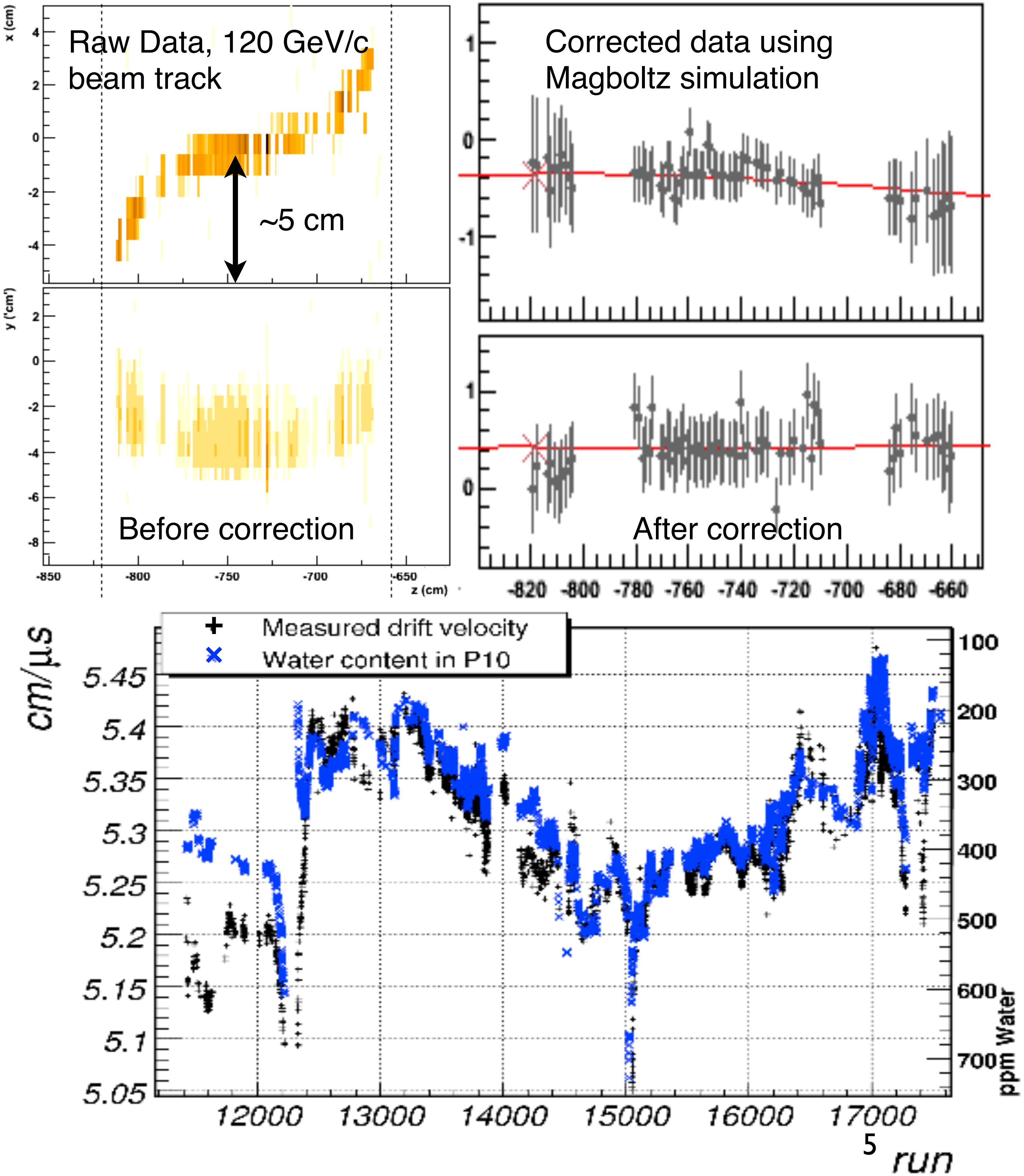


Time Projection Chamber (TPC)



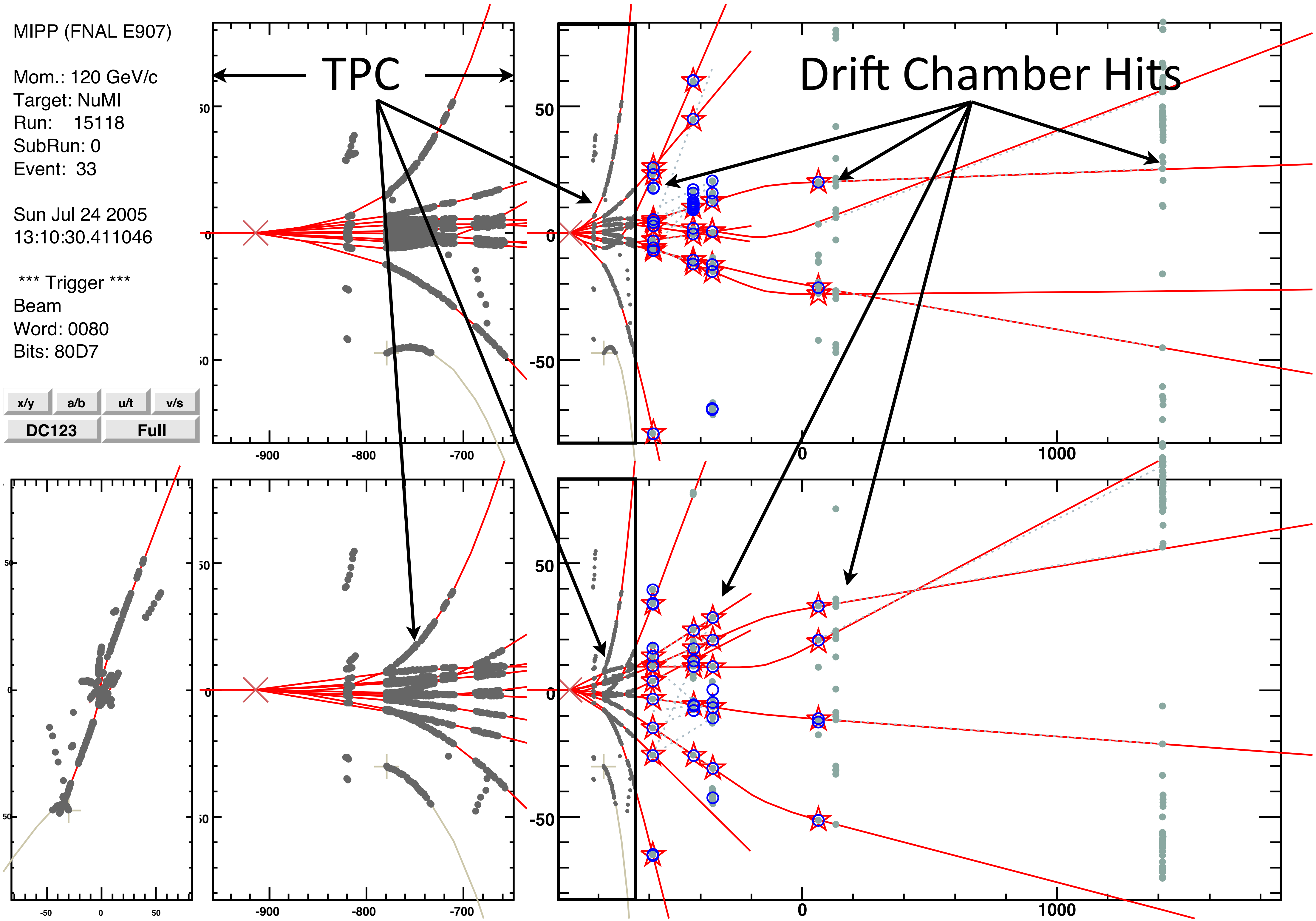
- Centerpiece of MIPP, originally built for the EOS experiment and used in several other prior experiments.
- Measures track trajectory in 3D: (x,z) position → pad locations, y position → drift time.
- Active volume of ~1 m^3 and a resolution of ~0.5 cm^3.
- PID via <dE/dx> below ~1 GeV/c.

TPC Calibrations



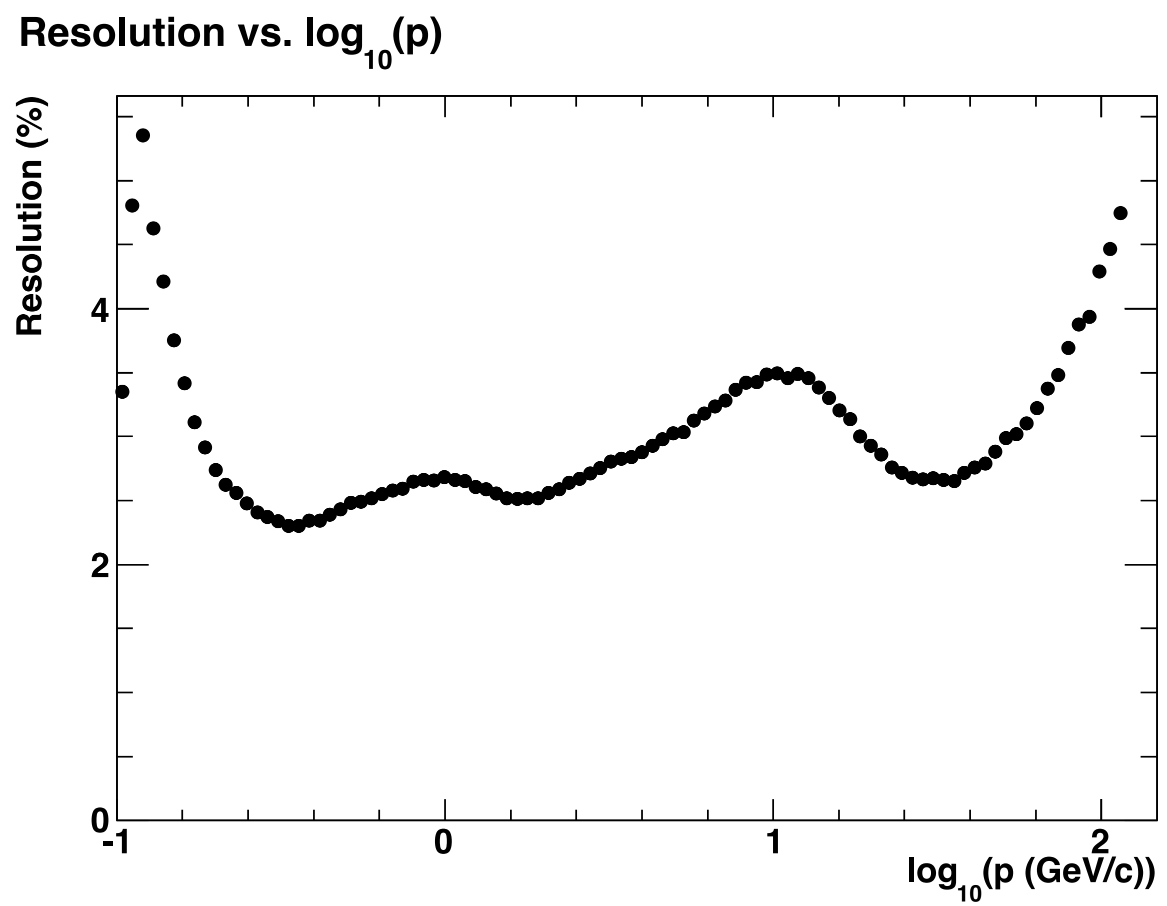
- Inhomogeneous magnetic field causes drift electrons to deviate from straight-line path to pad plane on bottom on TPC. Deviations of up to ~5 cm are observed!
- Using a map of the magnetic field and the Magboltz simulation, we correct these ExB drift effects to the level of ~90% (~2 mm worst case).
- Electron drift velocity is found to be run/time dependent: sensitive to the water contamination in the P10 gas!
- Time-dependent corrections to the drift velocity are made and $\delta v_D / v_D \sim 1\%$.

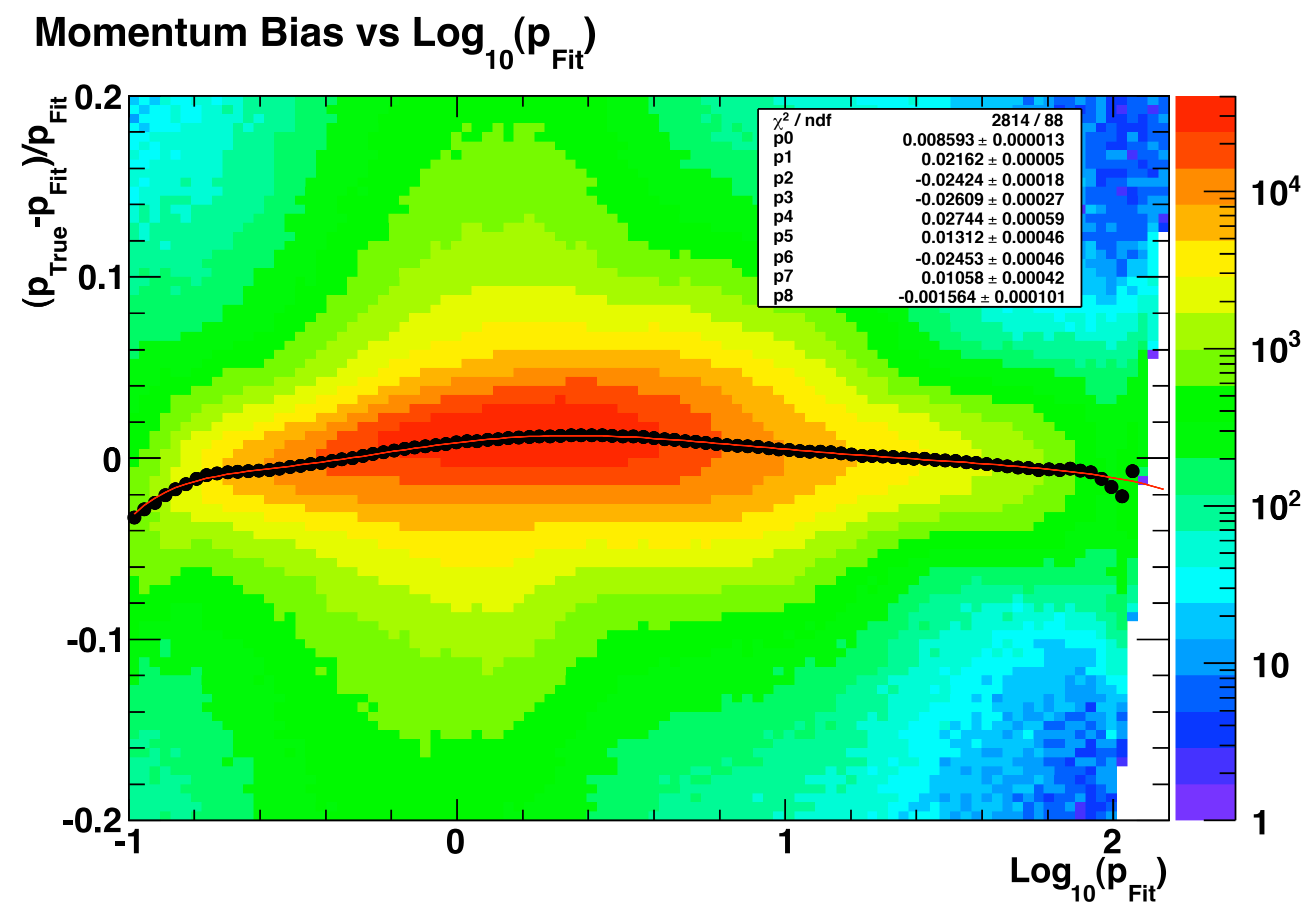
Global Track Reconstruction



TPC track segments are matched to downstream drift chamber hits, momentum is determined from bend in both magnets.

Momentum Resolution and Bias

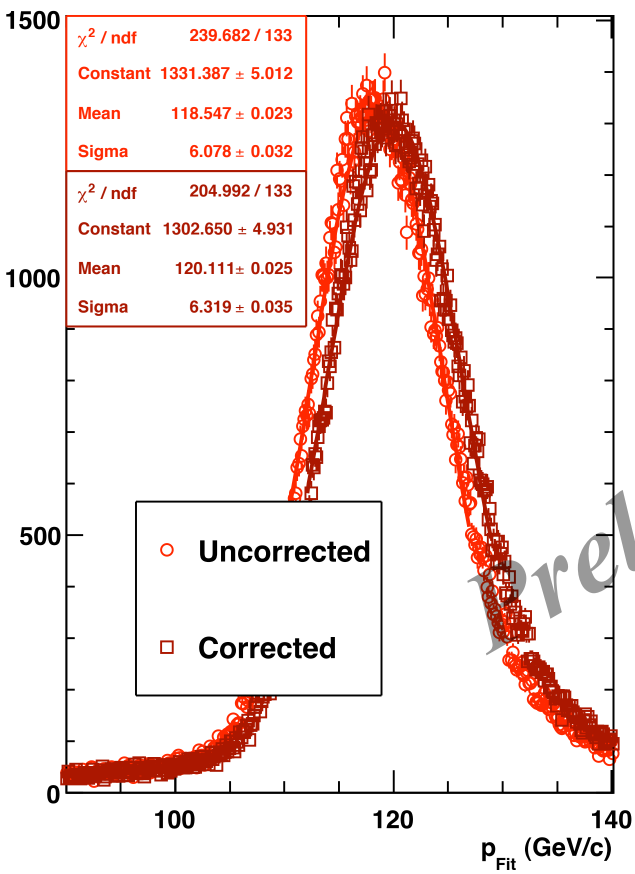




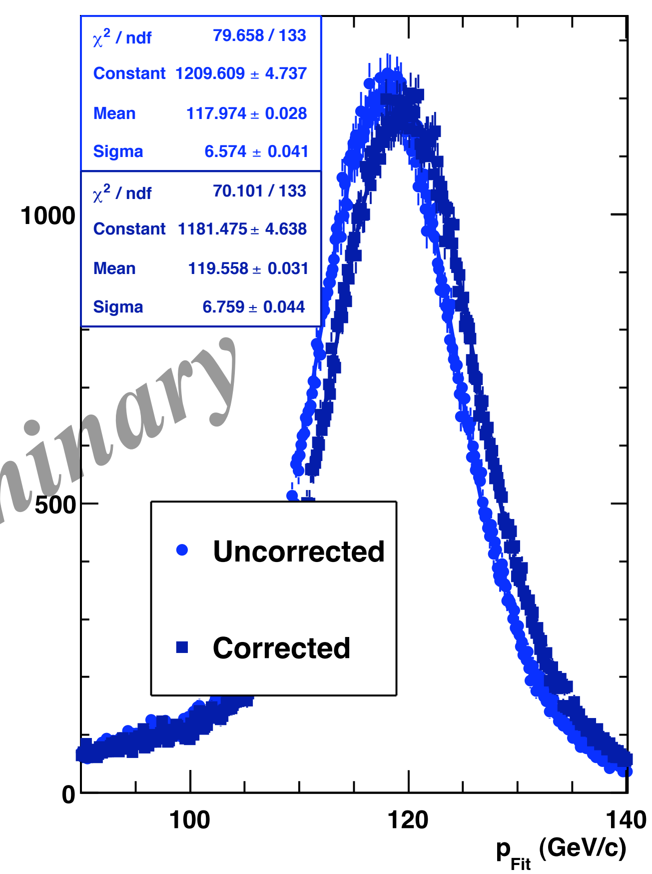
- Black points determined by fitting central peaks of slices of dp/p to Gaussian.
- Momentum resolution is < ~5%
- Bias < ~2%. Correction is applied and has a very small uncertainty.
- Transverse momentum resolution is < 0.02 GeV

Absolute Momentum Scale

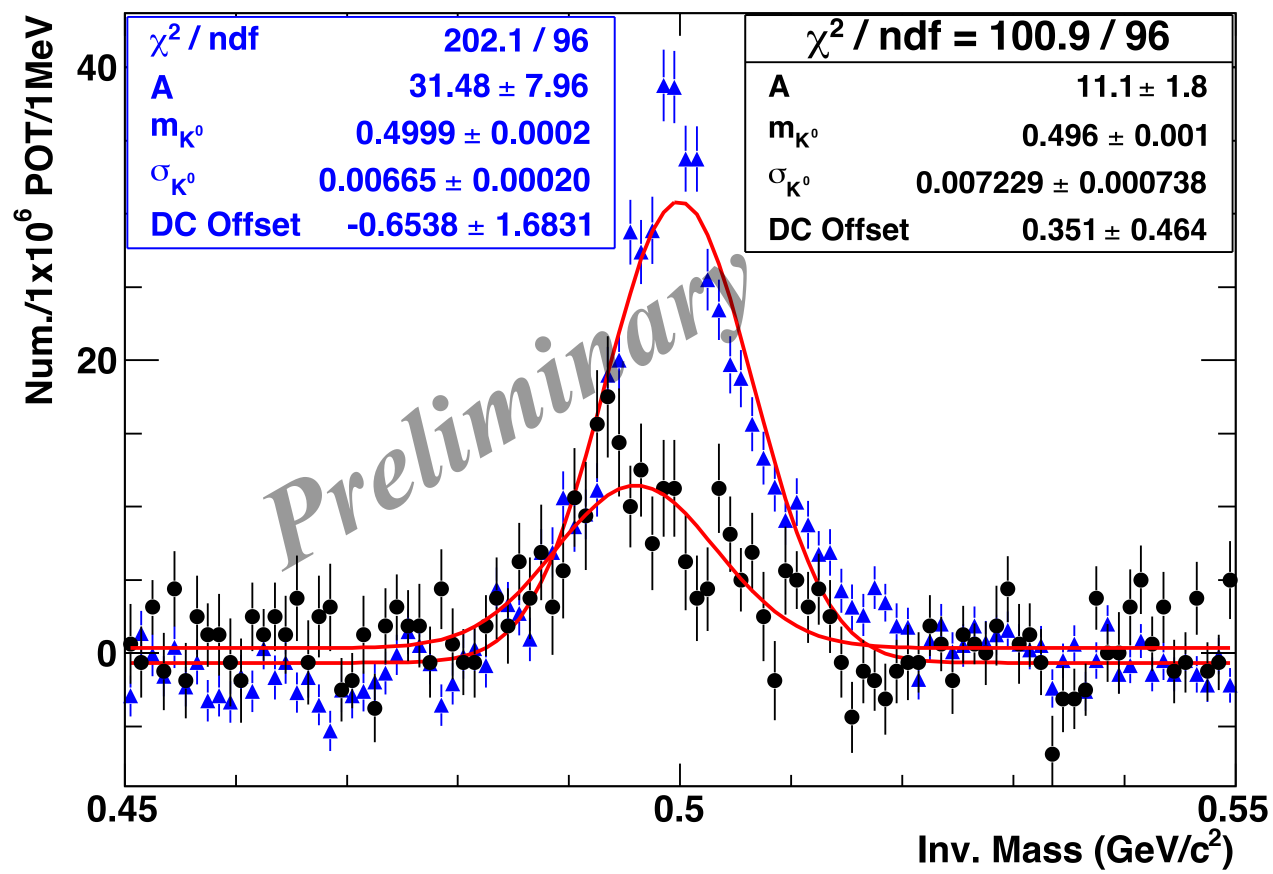
NuMI MC



NuMI Data

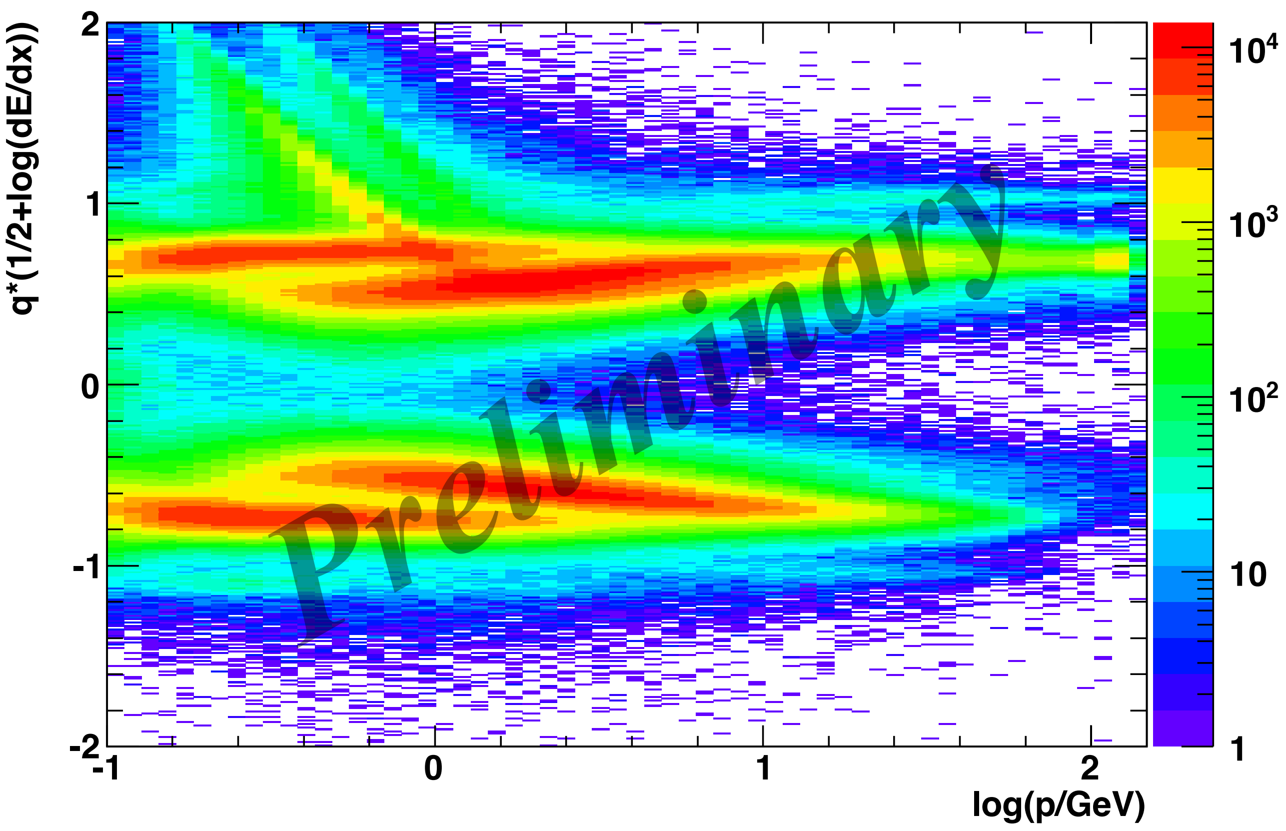


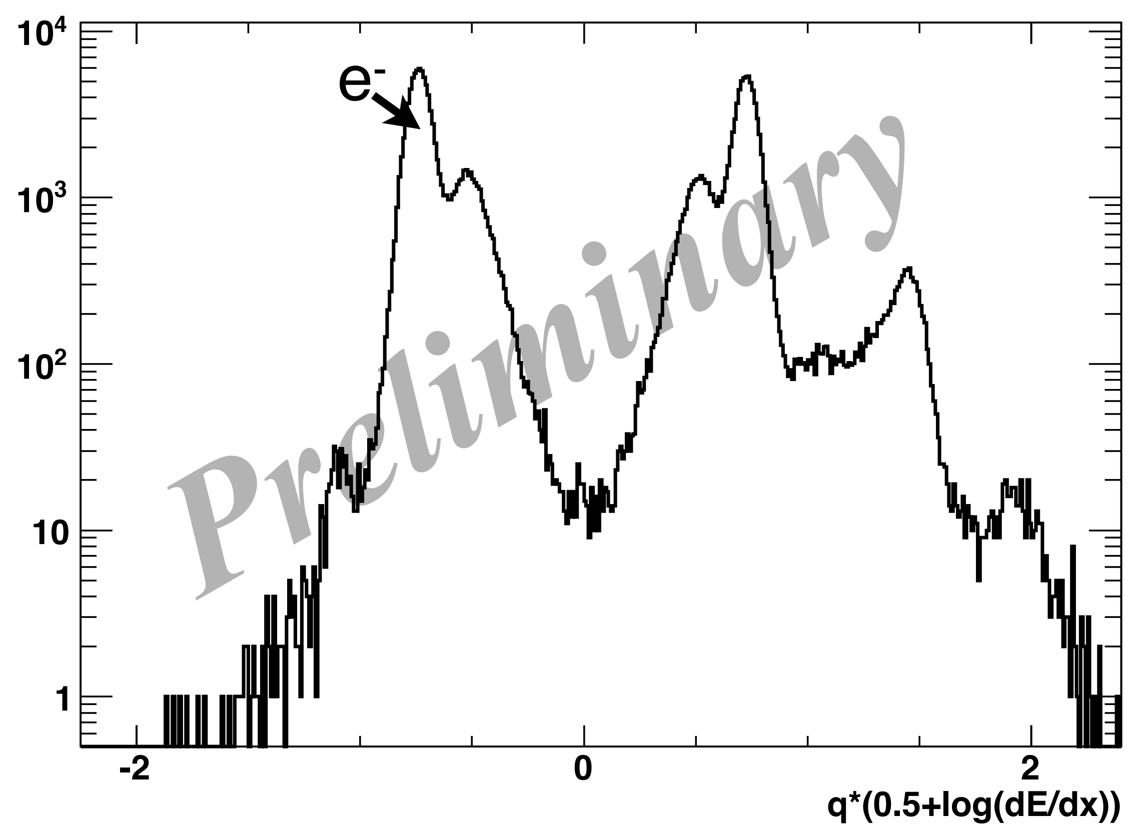
Bkg-Subtracted Inv. Mass Distribution, NuMI MC, dz Cut



- After momentum bias correction, single proton beam data and MC agree.
- Reconstructed K^0 invariant mass using tracks with p < 2 GeV/c indicates systematic offset of ~-1%.

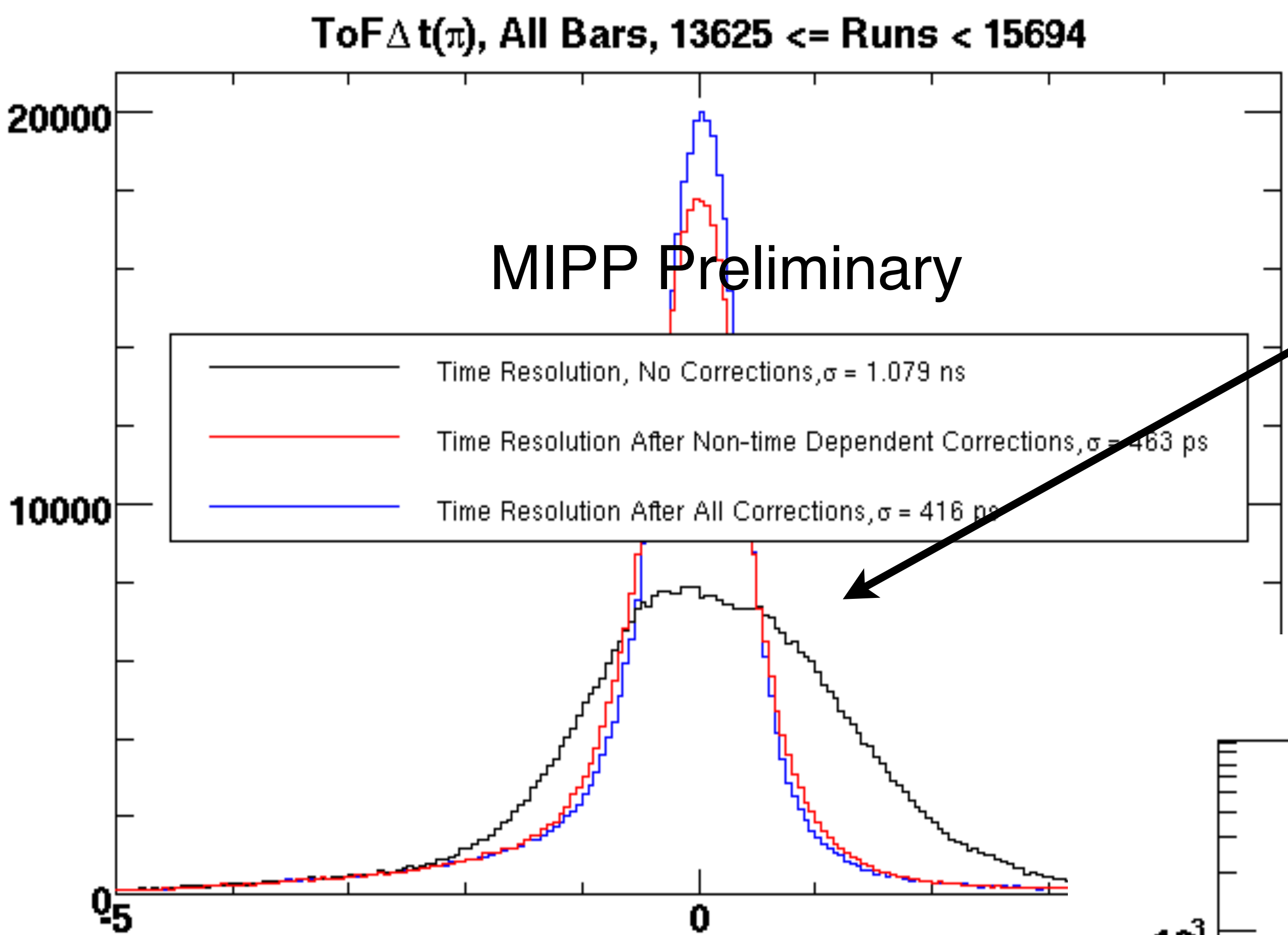
TPC PID Performance



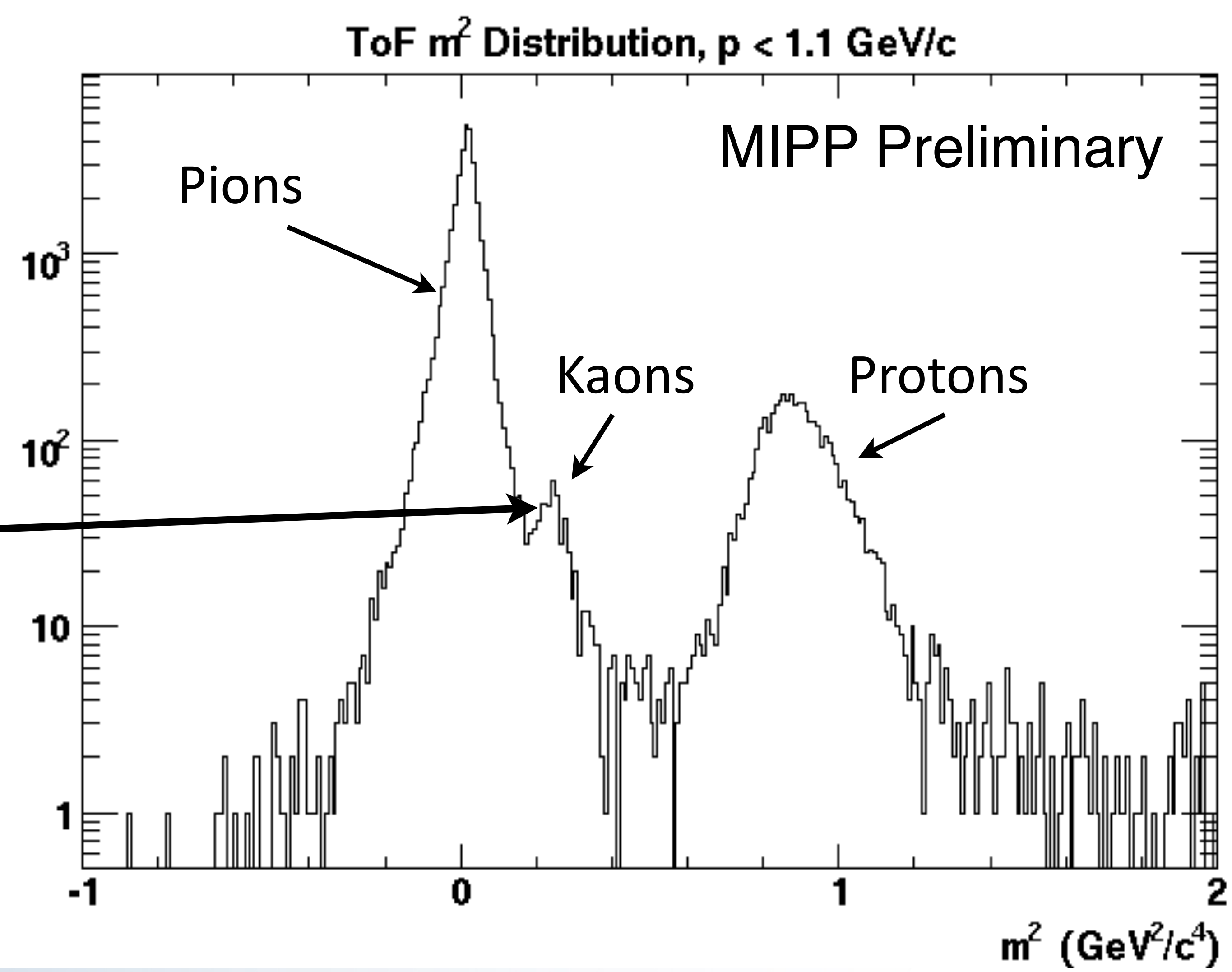


- TPC data are calibrated such that <dE/dx>(π) is 1 for p = 0.4 GeV/c and give expected Bethe-Bloch functional form.
- <dE/dx> resolution ~10%.
- Clean π, p separation between 0.2 and 1.2 GeV/c.

ToF PID Performance

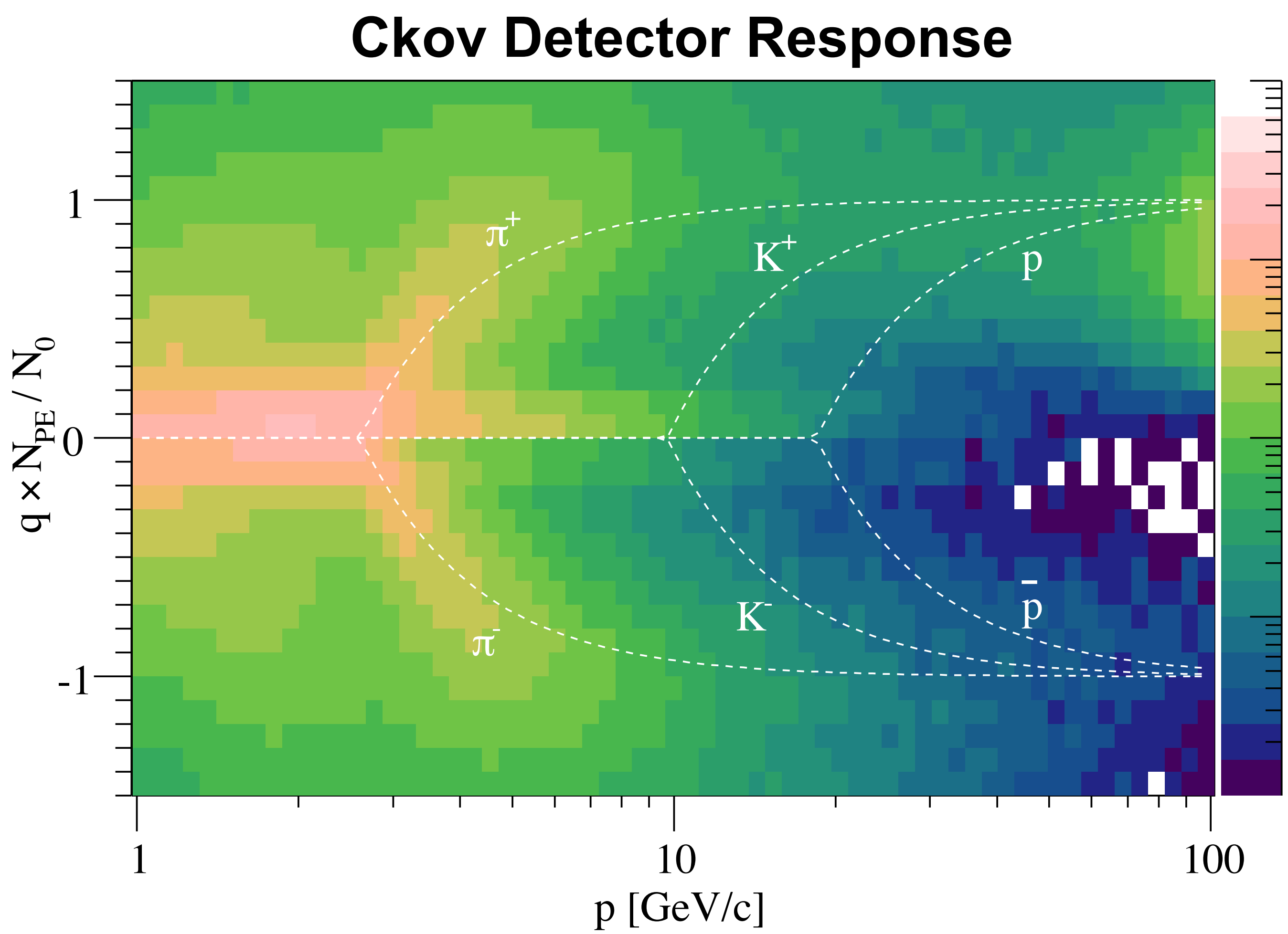


Data-driven calibration improved timing resolution by about a factor of 2.5

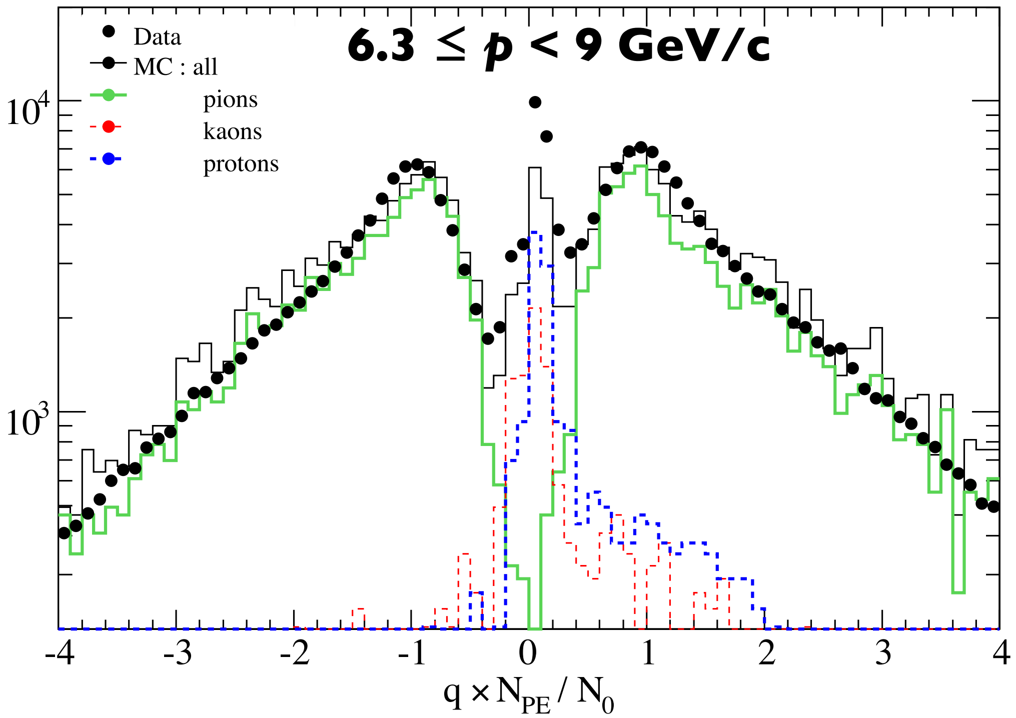


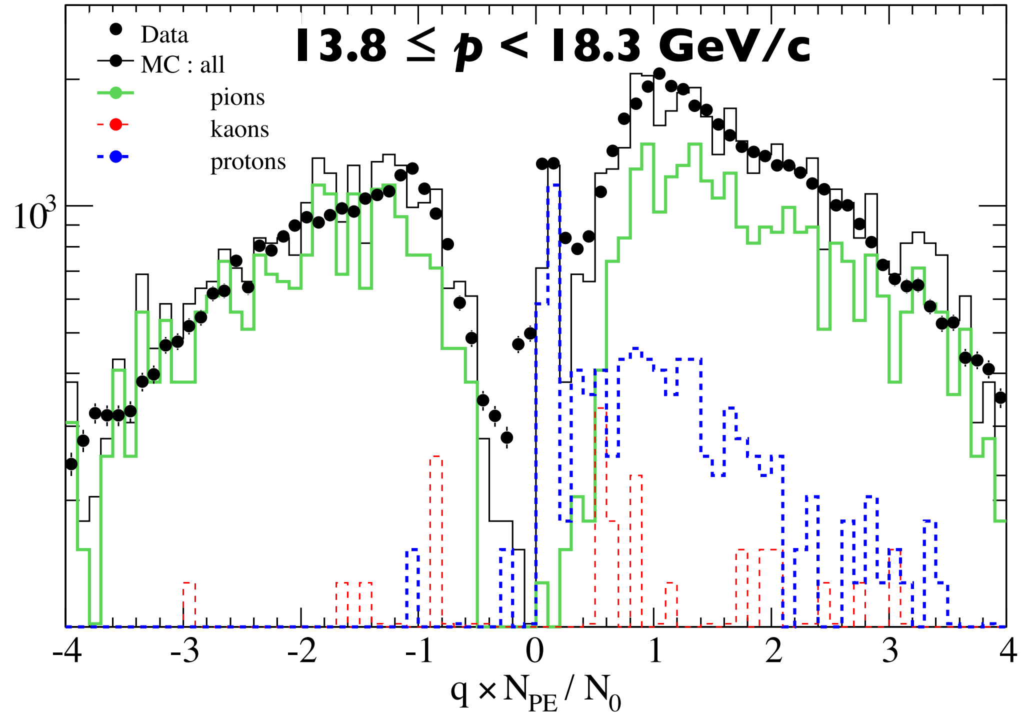
Kaon peak clearly visible in ToF m^2 distribution!

Ckov PID Performance



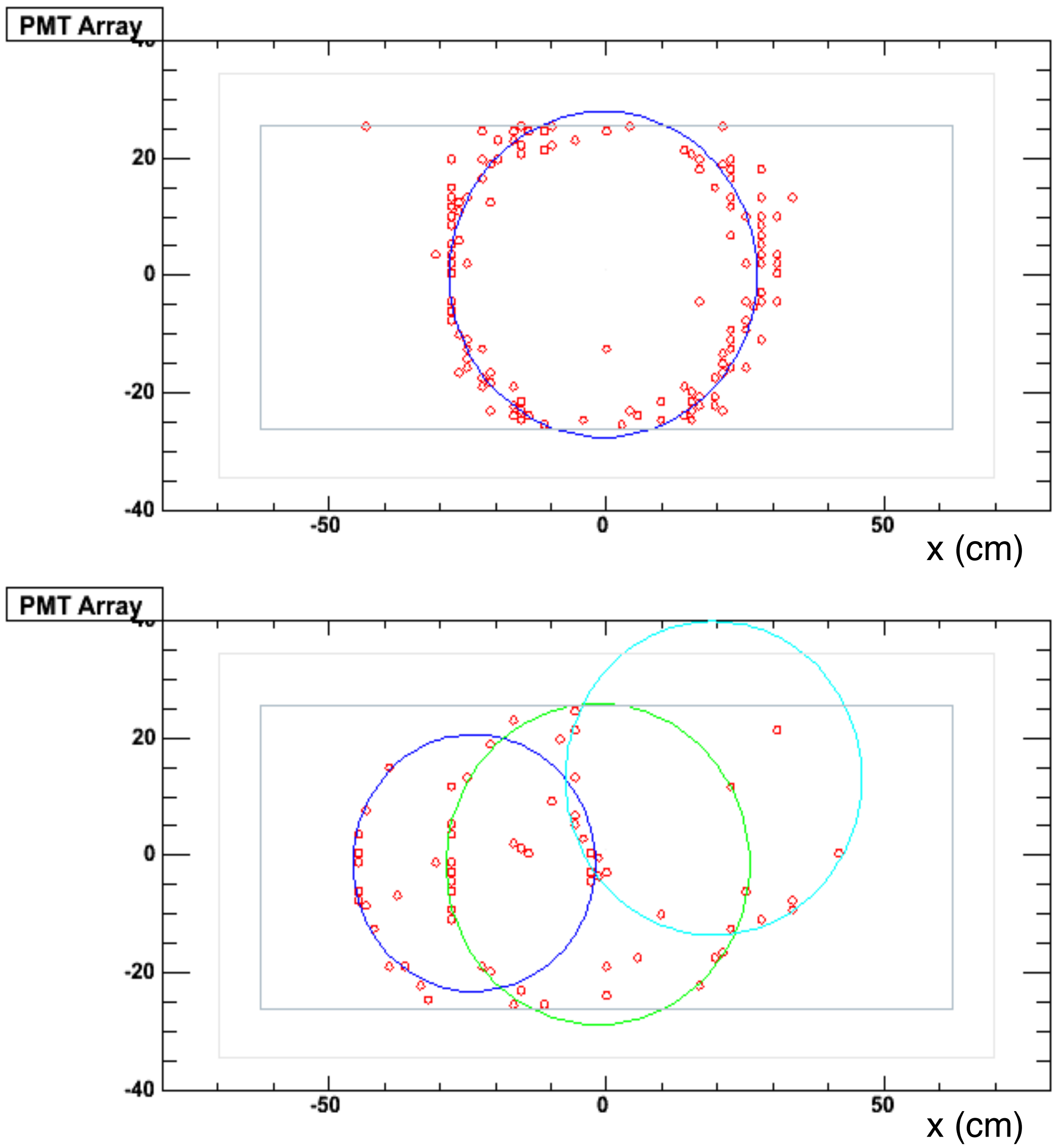
- Since all mirrors have a different response, each measurement of Npe is normalized to that of a β=1 particle.
- Pion "turn-on" clearly visible; proton "turn-on" also visible in slices of momentum.
- Shape of normalized response dist. in MC agrees very well with data.
- Data-driven calibration of 96 mirrors found detector response gives <10 pe/β=1 track.

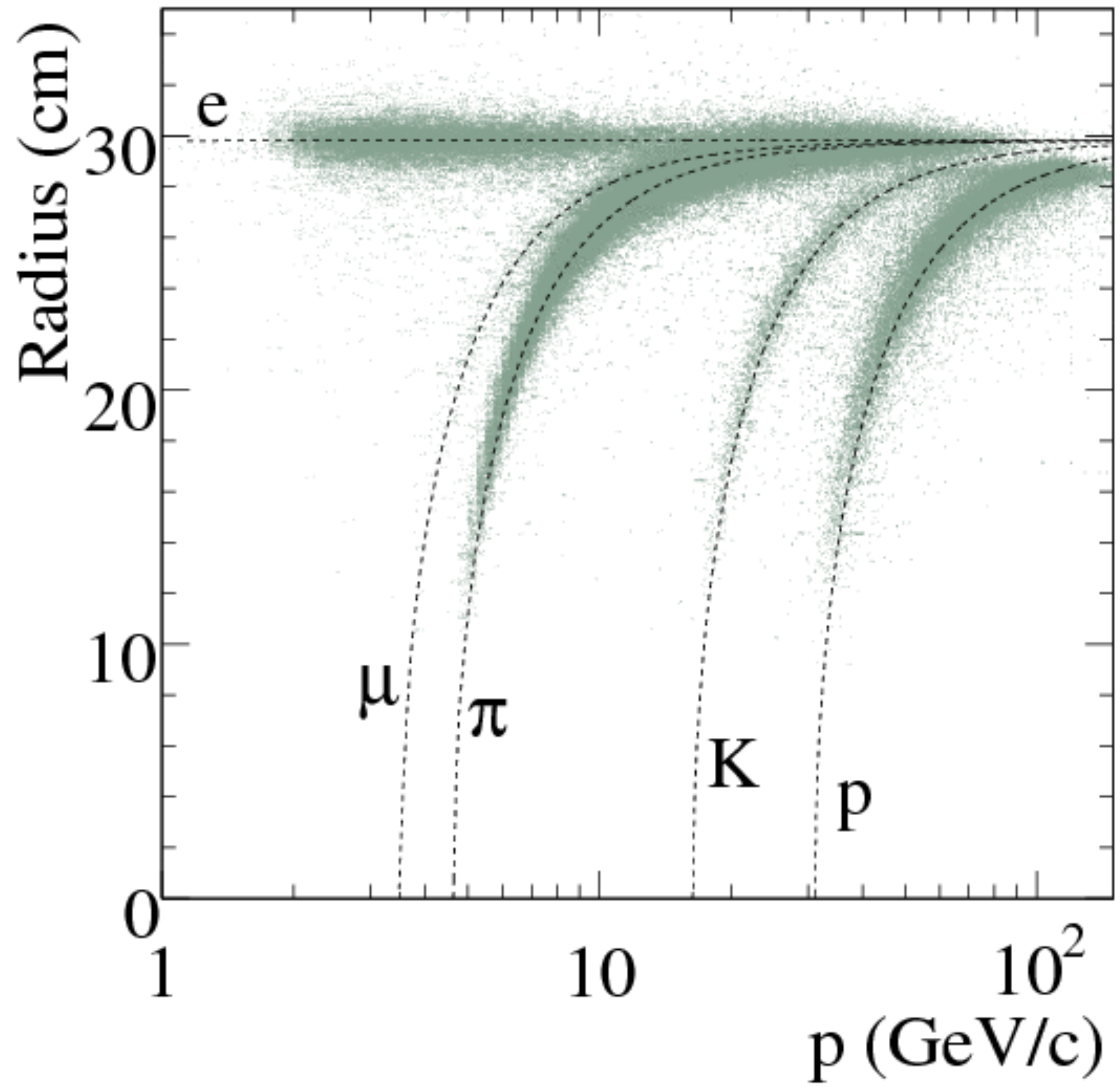




- Must only consider "isolated" tracks passing through mirrors; reject ~50% of Ckov PID data.

RICH PID Performance



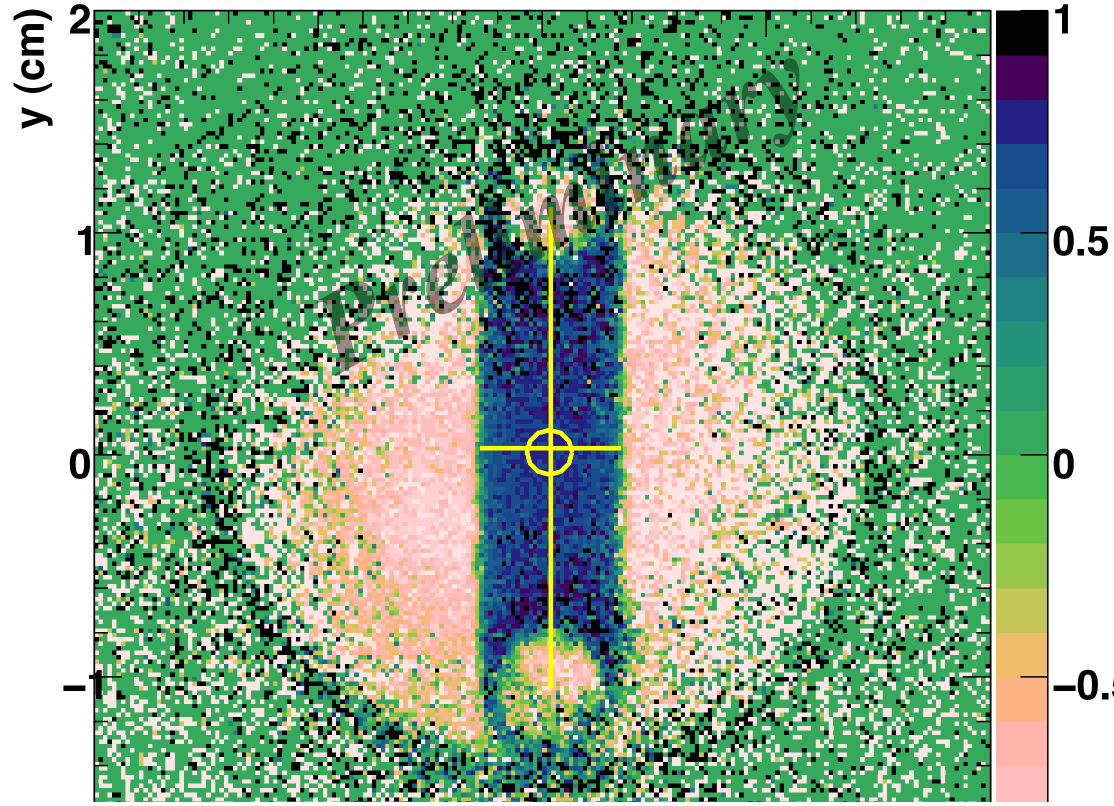


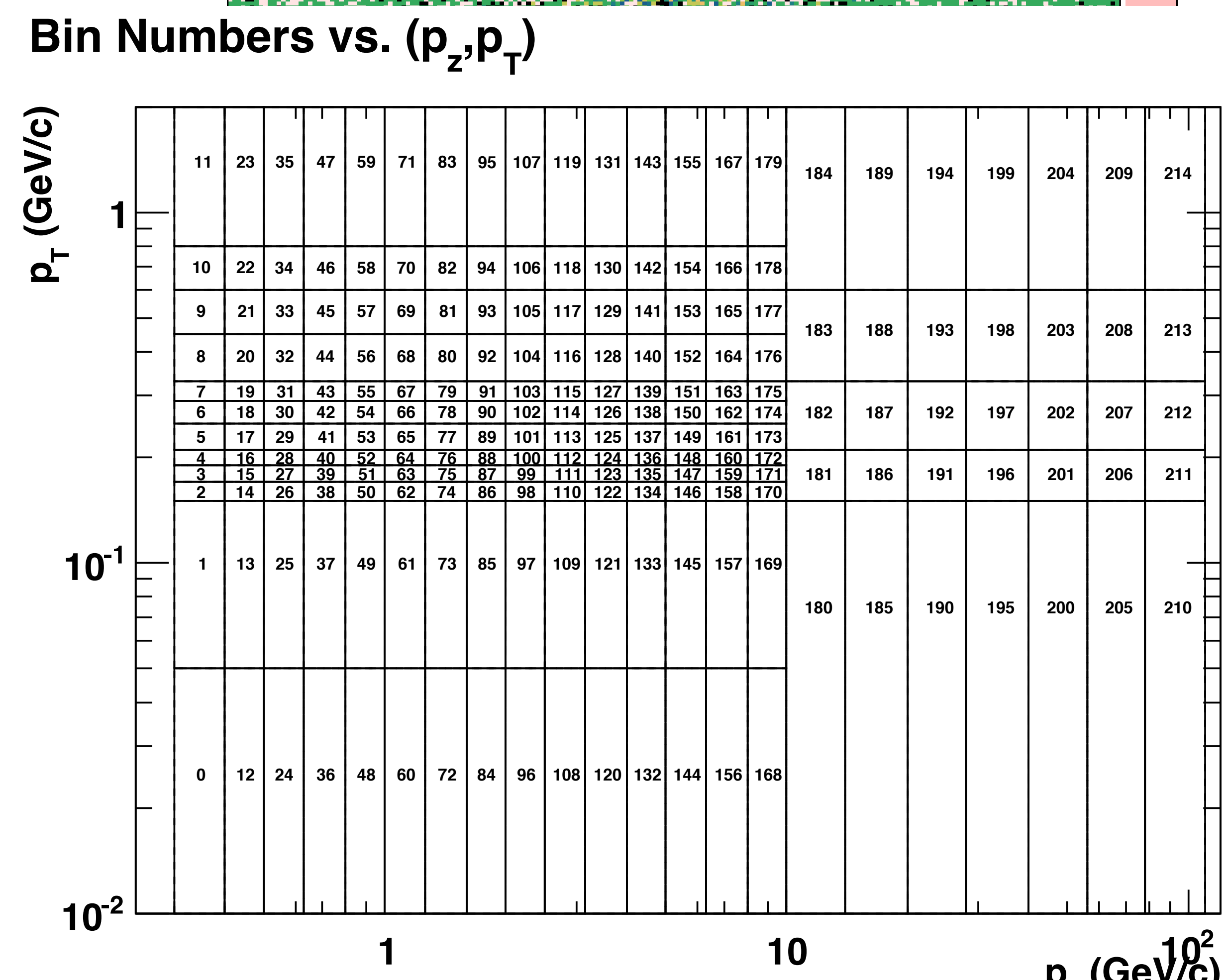
- Ckov light ring formed on array of ~2300 1/2" PMTs.
- Ring radius ~ Ckov angle ~ velocity.
- 3σ π/K separation up to 80 GeV/c, 3σ p/K separation up to 120 GeV/c

Status of the NuMI Target Analysis

NuMI Target Analysis

- MINOS adjusts their predicted ND neutrino energy spectra to agree with the measured spectra using (p_z,p_T)-dependent weights; these weights are an empirical fit, similar to the BPMT parameterization.
- The goal of this analysis is to provide similar weights to adjust the hadron production prediction off of the NuMI target with a direct measurement of the particle yields.
- The MIPP results will be particle yields, binned in (p_z,p_T).

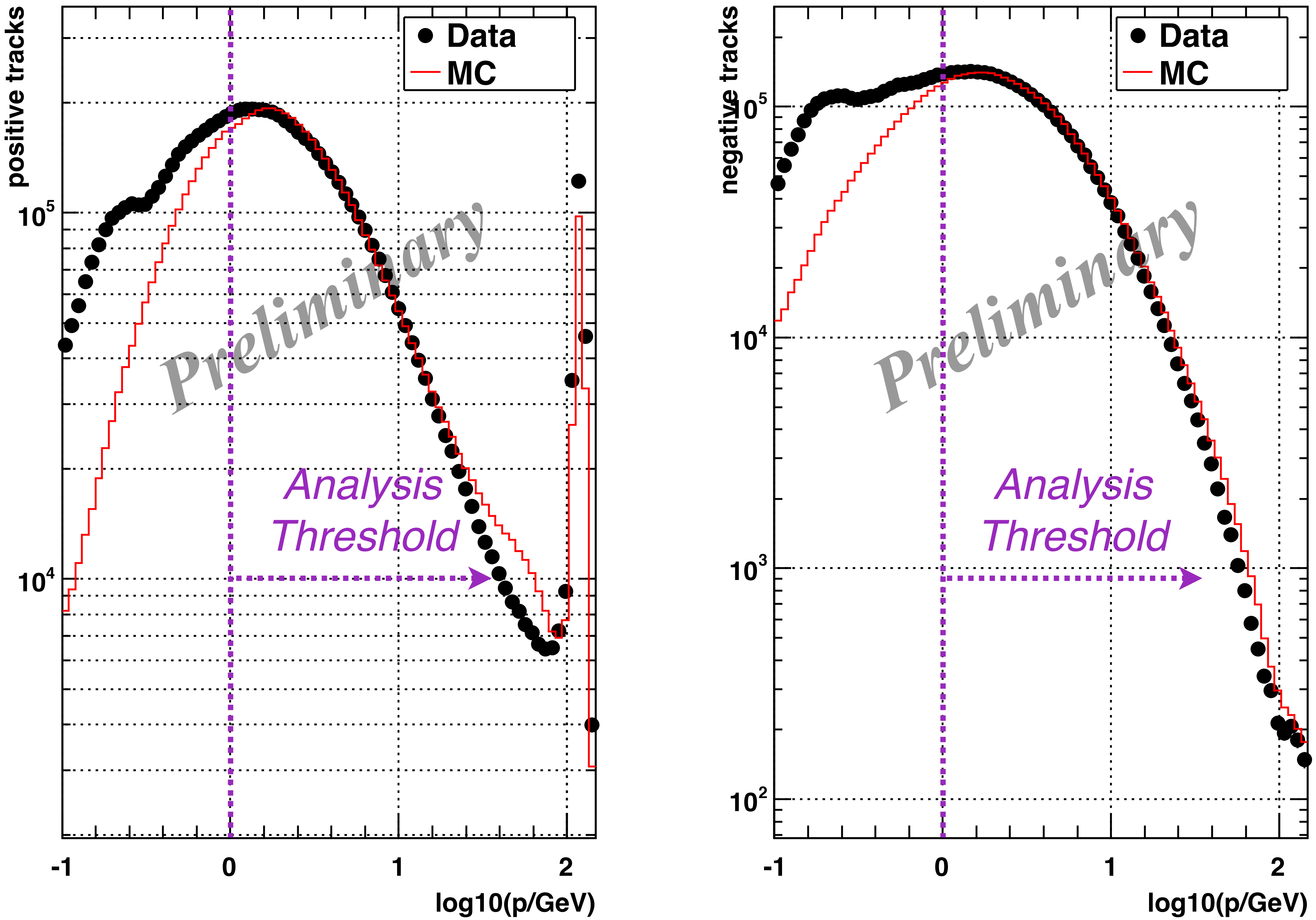




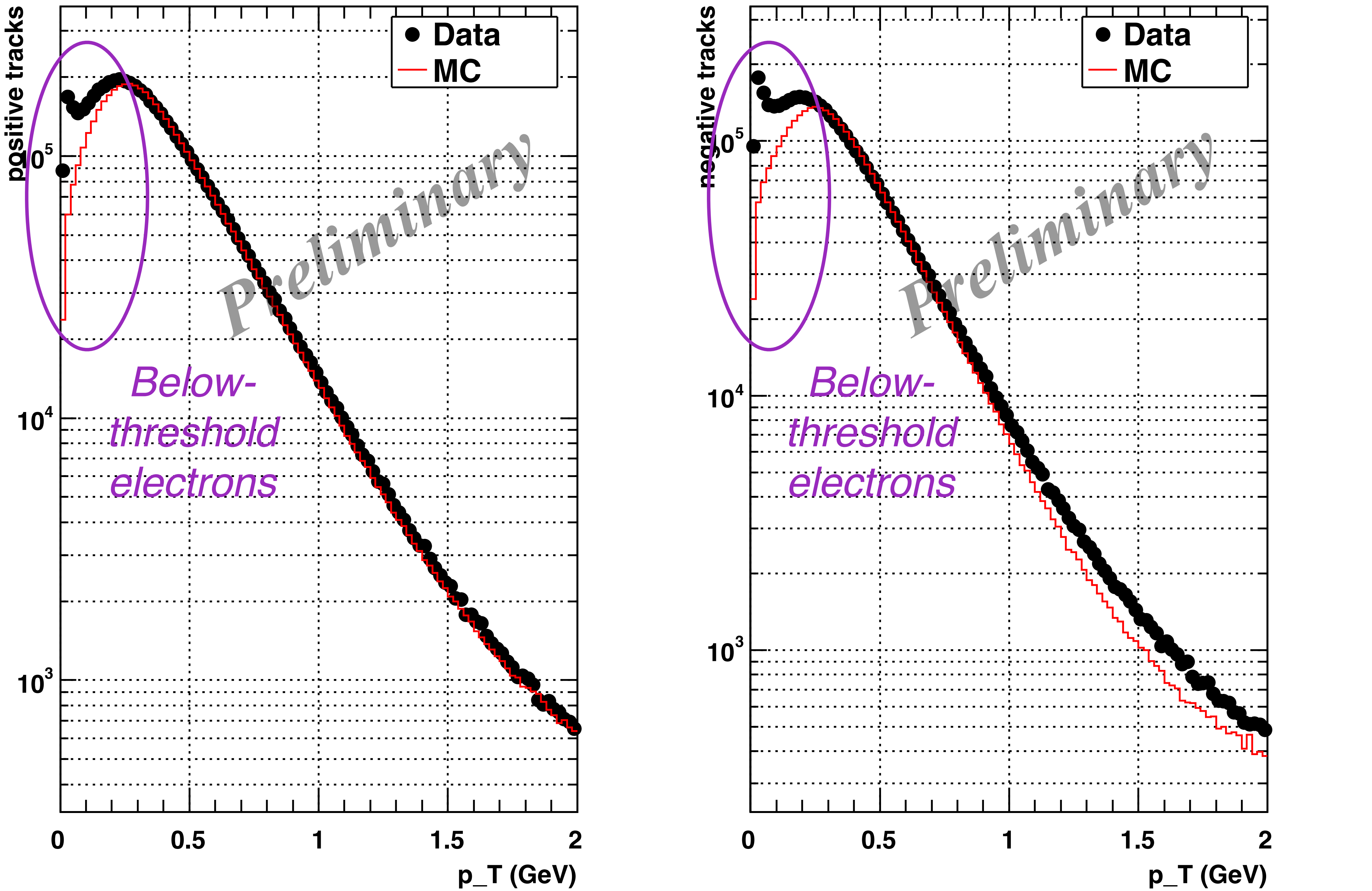
Where We Are With the Analysis

- I had been making good progress with the analysis before I made the choice to focus on NOvA in early 2010:
  - Event selection criteria finalized (begin with 2.11×10^6 POT, end with 1.45×10^6 POT)
  - Momentum bias and scale corrections finalized. Estimates on uncertainties on these are quite small compared to our proposed (p_z,p_T) bin sizes.
  - (p_z,p_T) bins determined based on $\sigma(N(\pi+)) < 3\%$. There are 133 bins. In most cases (at low momenta), $\sigma(N(\pi+)) < 1\%$. Probably don't need that many bins, so to expedite the analysis, one could easily decrease the number of bins by factor of 2-5 and still have a big impact on flux constraints.
  - Large MC data set generated **(but needs further tuning)**
  - Analysis (fitting) strategy outlined and mock data tests had begun on the approach. **This needs to be revisited**, in particular there may be better/quicker ways of doing this using modern/standard tools (eg, Root TMVA).
- Some further progress has been made on the NuMI target analysis by other MIPP colleagues since I "disappeared" **[need details here!]**.

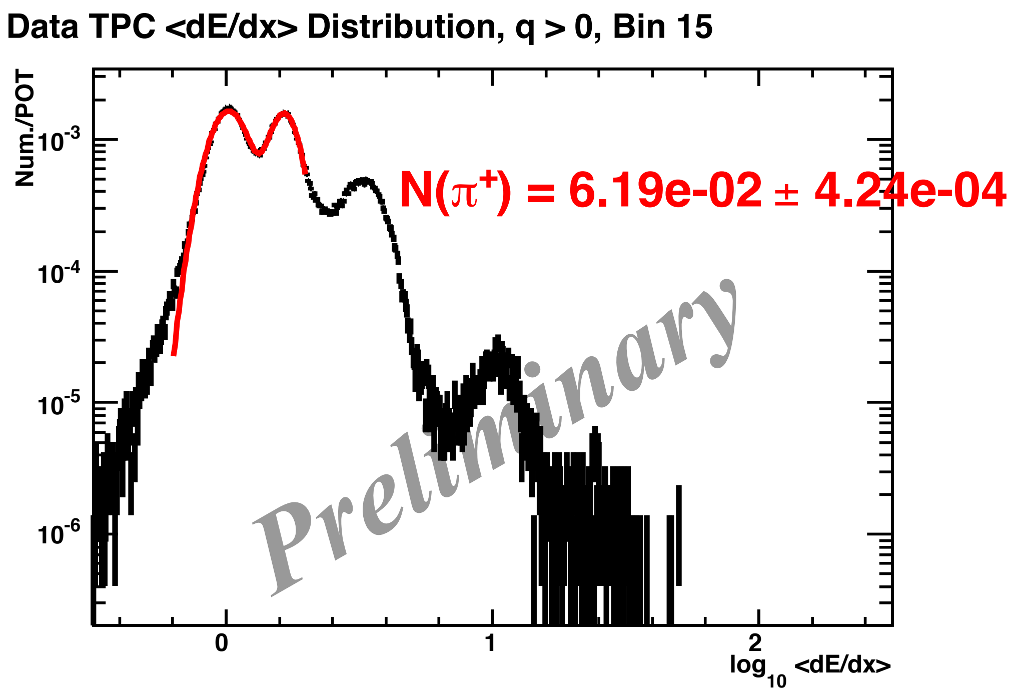
Comparison of Data and MC p_z Spectra

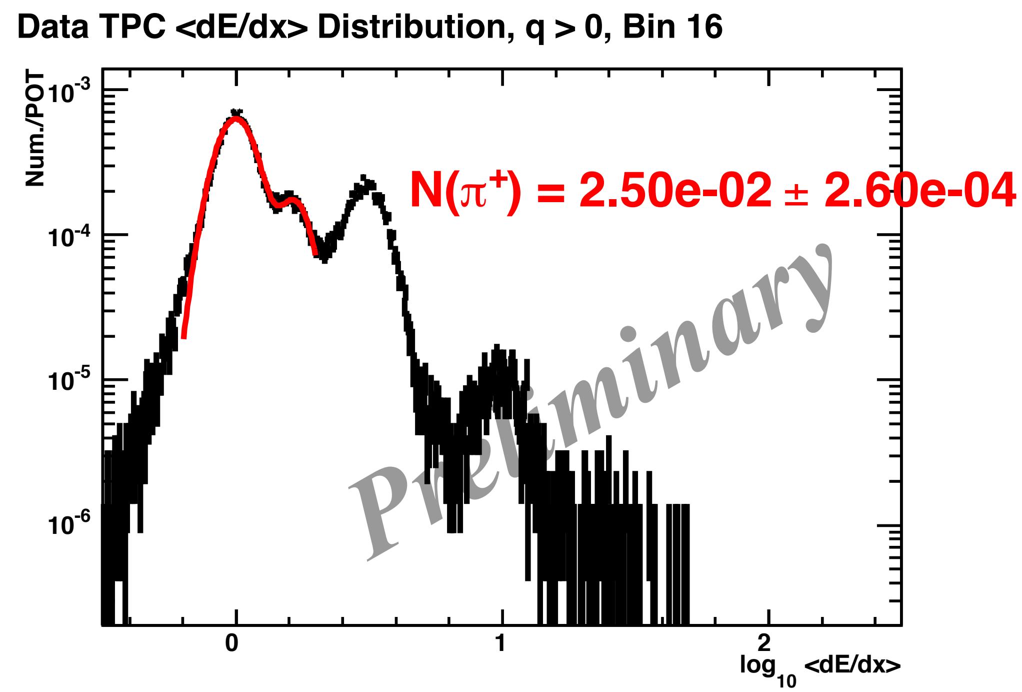


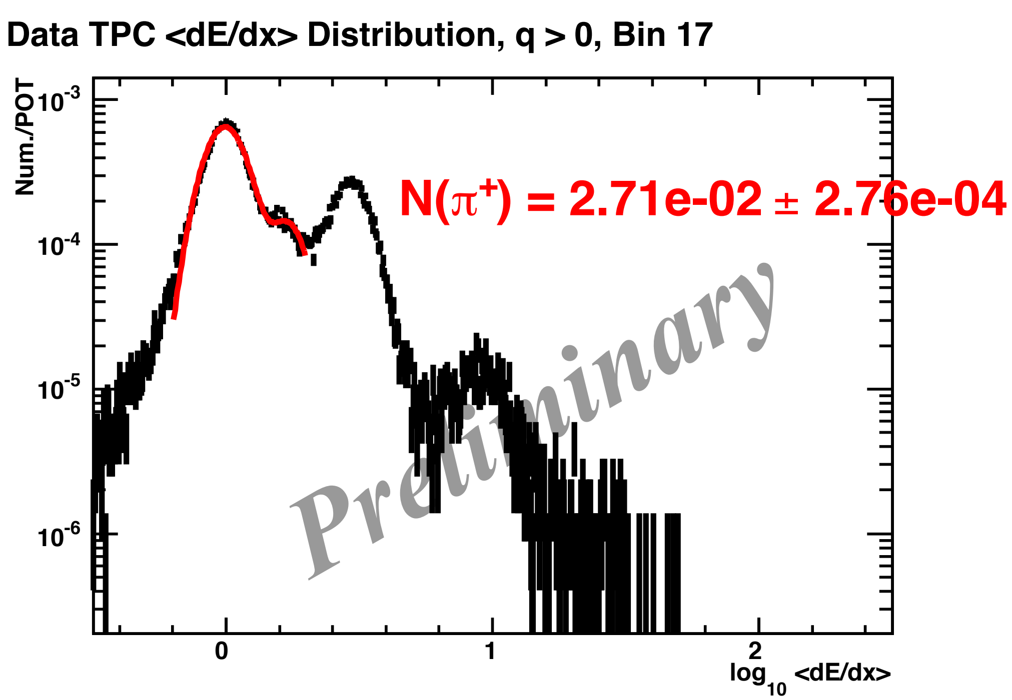
Comparison of Data and MC p_T Spectra

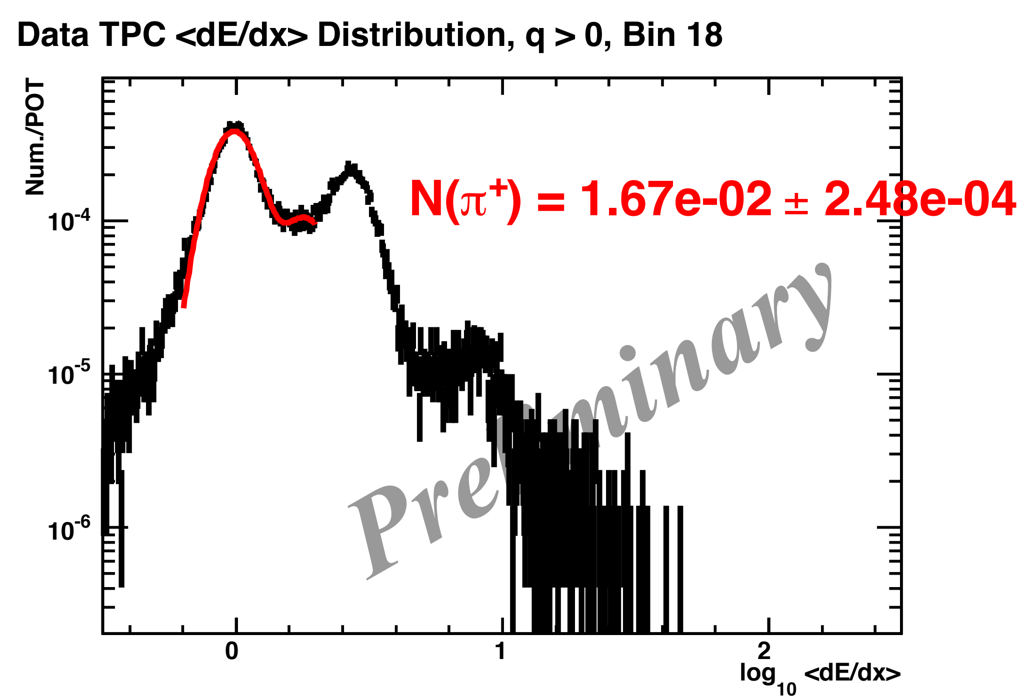


Preliminary Pion Yield Measurement (TPC-only)



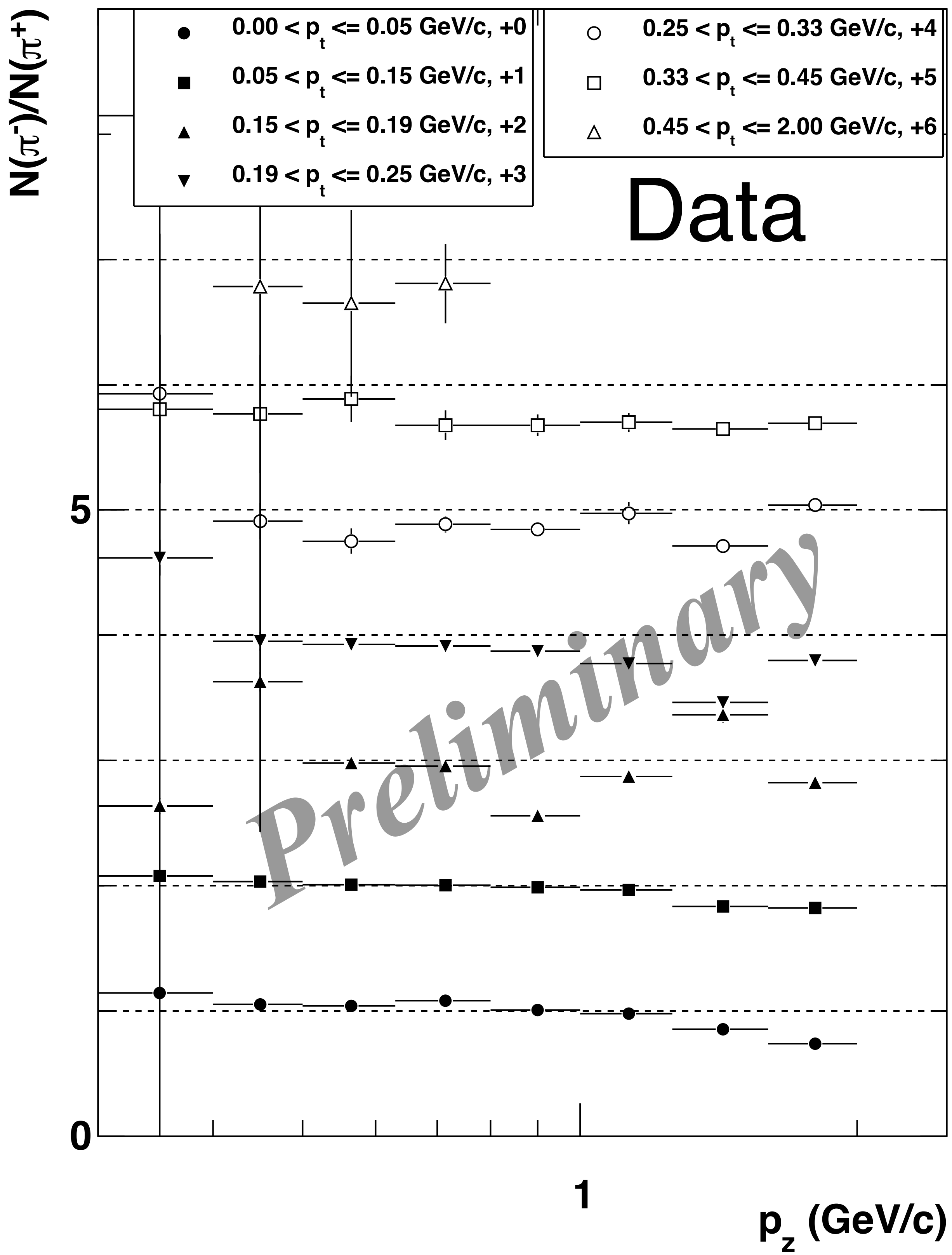




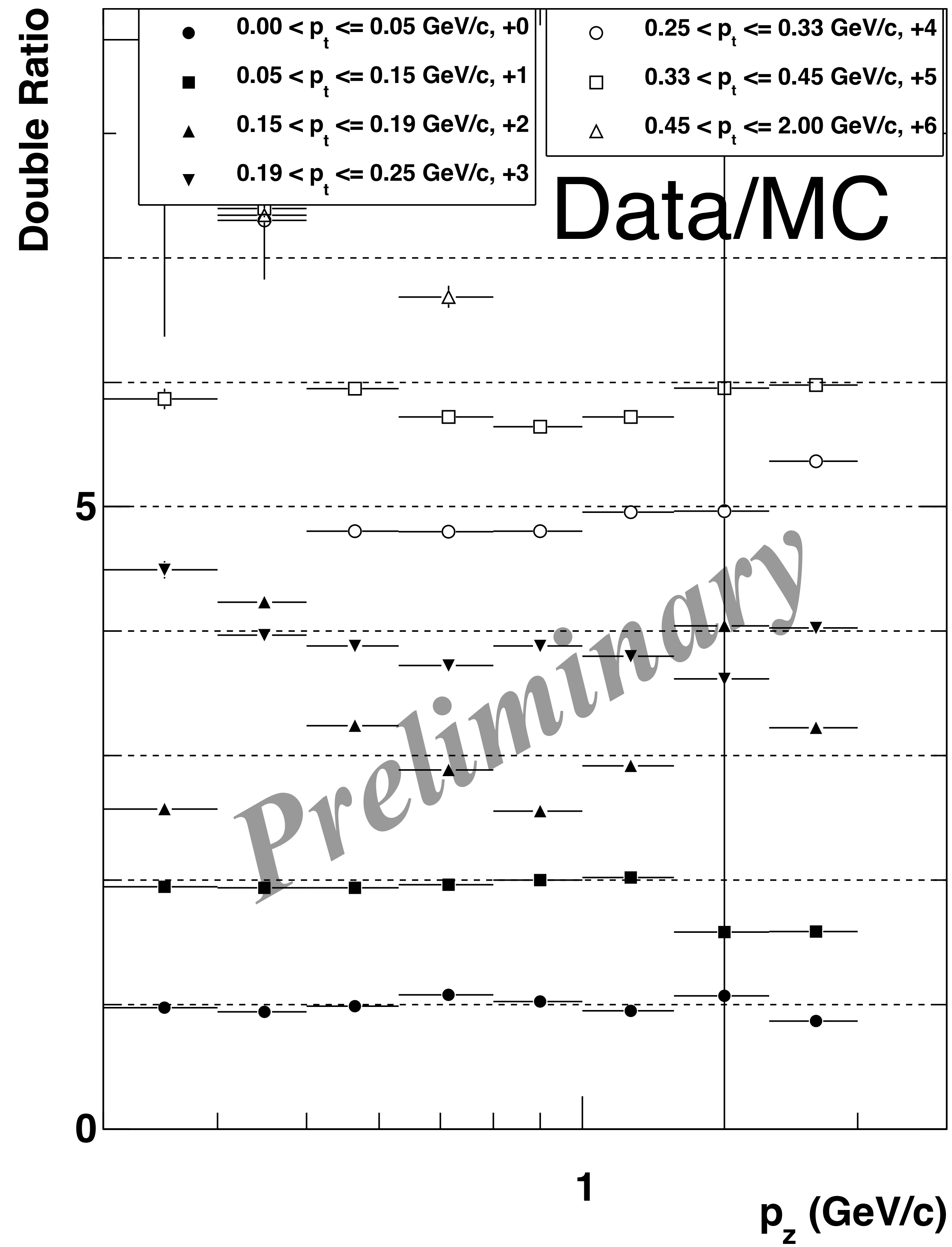


Preliminary Pion Yield Measurement (TPC-only)

$N(\pi^-)/N(\pi^+)$ vs. p_z



Data(π^-/π^+)/MC(π^-/π^+) vs. p_z



Thoughts on Possible Paths Forward

- PID response in MC can be tuned “by hand” using the above files to be “good enough”. ToF and RICH need some fine-tuning, TPC and Ckov should be ok now.
- Using Root tools (TMVA, TSVD) could make analysis fairly straightforward (not saying it’ll be “easy”!)
  - TMVA for PID
  - TSVD for **p** deconvolution.
- Low-energy $K^{\pm}$ and K-short production measurement is relevant for NOvA NDOS analysis, so I hope to work on this early next year (2013), BUT:
- Help from experiments that would benefit from these data would be appreciated, and it should not be difficult to get postdoc up and running. Eg, flat Root ntuple format of data and MC exists.

What Needs to Get Done

- Tune the MC PID response for the ToF, Ckov and RICH (the TPC is in good shape)
  - ToF and RICH m^2 distributions need some minor adjustments to make MC $\langle m^2 \rangle$ and $\sigma_m{}^2$ match the data
  - At first glance, Ckov MC looks very good.
- Continue the mock data fits, make fits more robust. Possibly investigate alternatives to proposed analysis strategy. Measurement of Kaon weights presents a big challenge for most bins...
- Create laundry list of systematics, use both mock and real data to estimate size of errors.
- I'm sure I'm forgetting some things here...
- Manpower: help with the analysis would be very welcome. Student/postdoc could work on any of the above tasks, as well as build infrastructure for comparing to NuMI/MINOS.